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Isolated Tuber-unit Seed Plots for the Control of Potato Virus Diseases and Blackleg in Northern Maine

PLANTING POTATOES BY TUBER UNITS

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BULLETIN 370

ISOLATED TUBER-UNIT SEED PLOTS FOR THE CONTROL OF POTATO VIRUS DISEASES AND BLACKLEG IN NORTHERN MAINE[1]

E. S. Schultz,[2] Reiner Bonde,[3] and W. P. Raleigh[4]

INTRODUCTION

One of the most important problems that confronts the potato grower of Aroostook County, in northern Maine, is the obtaining of seed potatoes which are free from mosaic and other virus diseases. The importance of this problem is due in part to the undesirable effects of these diseases on yield and quality. It is also due to the facts that approximately 150,000 acres of potatoes are planted each year in northern Maine, that this acreage annually requires about two and one-half million bushels of seed potatoes, and that on a large part of this acreage potatoes are grown for seed for use in other states.

Experiments have been described in numerous publications showing that insects transmit mosaic and other virus diseases. This information emphasizes the importance of growing healthy potatoes as far away as possible from diseased plants. It also indicates that it is necessary to remove diseased plants from partly healthy potato lots before insect vectors (transmitting or spreading agents) appear or become numerous, if the spread of disease from plant to plant in the same field is to be prevented. Isolated tuber-unit seed plots have been used with some success to check the natural in-

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[1] This paper is based upon investigations conducted as a cooperative project between the Division of Horticultural Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Department of Plant Pathology of the Maine Agricultural Experiment Station. Unless otherwise indicated the work was done in Aroostook County in northern Maine.

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crease of potato virus diseases (Folsom, Schultz, and Bonde, 1926, pp. 94-98, 101).[5]

Our earlier experience with different varieties and different virus diseases showed that mild mosaic in the Green Mountain and Bliss Triumph varieties was more difficult to control in northern Maine than leafroll and spindle tuber. Thereupon in this locality our work was confined primarily to the control of mild mosaic.

Experiments with several strains of Green Mountains, which manifested from 0 to 12 per cent mild mosaic and which were grown in an isolated tuber-unit seed plot on Aroostook Farm (near Presque Isle) from 1923 to 1926 (Folsom, Schultz, and Bonde, 1926, tables 11 and 13; Folsom, Owen, and Smith, 1931, table 4) had shown that although roguing kept mild mosaic from spreading to more than 12 per cent of the plants, it had not controlled this disease satisfactorily. Therefore it was decided to grow only one strain on a plot. From 1927 to 1931 only one strain of Green Mountains was grown on the isolated tuber-unit seed plot on Aroostook Farm. In addition to this plot, small isolated tuber-unit seed plots were located on commercial potato farms and in clearings in the woods in the vicinity of Presque Isle, Maine. Our results with all these seed plots are recorded in this bulletin.

AROOSTOOK FARM SEED PLOT

The Aroostook Farm seed plot was not sufficiently isolated to be considered ideal. In 1927 and 1930, it was located in an open field which was only 200 feet from the nearest potatoes. (See Table 1 for data pertaining to the Aroostook Farm seed plot.) During the remaining seasons (1926, 1928, 1929, and 1931), the seed plot was located in a three-acre field surrounded on three sides by woods and was approximately 1000 feet from the nearest field of potatoes.

This procedure as to location permitted a three-year rotation of potatoes, oats, and clover. In two consecutive seasons the seed plot covered respectively one or the other half of this three-acre field, and every third year, or in 1926 and 1929, it was located in the open field previously mentioned.

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[5] Reference is made by name of author and year of publication to Literature Cited, on pp. 31-32.

The Aroostook Farm seed plot may be considered as rather typical for the conditions as they exist in the concentrated potato regions of northern Maine. The recorded results can serve as a fair example of what may be expected from conducting a tuber-unit seed plot on any one of many farms. The seed plot varied from one and one-half acres to two acres in size, an area which would fulfill the need of each of many potato growers.

SOURCE OF SEED POTATOES

The lot planted in 1927 represented one of the four Green Mountain strains that had been rogued and grown in the isolated seed plot in 1926. In 1928, a part of the same strain was brought in from Highmoor Farm located in southern Maine. This substrain had been taken there from Aroostook Farm in 1924, and had since been grown there in an isolated seed plot, where isolation and roguing had controlled mosaic more effectively than on Aroostook Farm. From 1928 to 1931, this Green Mountain substrain was grown on the Aroostook Farm seed plot.

TUBER-UNIT METHOD OF PLANTING

To facilitate inspection and roguing and thus to lessen the chances of disease transmission from plant to plant within the plot, the seed potatoes were planted in tuber units. There were four hills in each unit. Seed pieces within the unit were placed at 12-inch intervals and the tuber units were separated by 24-inch spaces. That is, a blank hill was left after each of the successive units.

The various methods of planting seed plots are discussed more fully in a later section of this bulletin. Probably the most accurate but also the most laborious and time-consuming planting method involves cutting and dropping the seed pieces into the open furrow by hand. This method was employed for the five seasons from 1923 to 1927. From 1928 to 1930, an automatic tuber-unit cutting and planting machine was used. This machine cuts and plants the seed by tuber units in one operation and its use is a rapid method for planting a seed plot. However, this planter occasionally cut two tubers at once, did not cut seed pieces uniformly, and frequently carried small seed pieces into the following tuber unit, so that a two-

man planter was used in 1931. This method involved cutting each tuber by hand into four seed pieces and putting them into a suitable compartment in a tray (Fig. 1). Several trays can be stacked

FIG. 1. Cutting seed potatoes for tuber-unit planting and placing the four seed pieces per tuber in a separate compartment of a tray or flat. Trays are stacked on 2-man planter as shown in Fig. 2. The bottom of these trays consists of "compo" board or "celotex" and the sides and partitions of 1½ inch laths. The outside dimensions of the trays are 16x26¼ inches which provides for 12 compartments. The dimensions of each compartment as measured to the center of the lath are 4¼ by 7½ inches.

in front of the planting wheel. Here the operator or picker can easily get the seed pieces and drop them into the planting wheel in tuber-unit order (Fig. 2). With the two-man planter method a more uniform stand and better spacing of the plants resulted than with the automatic tuber-unit planting machine.

FIG. 2. Planting the tuber-unit seed plot on Aroostook Farm by using the tray method. (See Fig. 1 for cutting.) Each compartment of a tray contains four seed pieces from one tuber. The seed pieces are dropped by hand in tuber-unit order in the planting wheel. By using a special planting wheel which is provided with a blank or blind pocket after every fourth compartment in the wheel one can easily plant the tuber units with skips between them.

INSPECTION AND ROGUING

The first inspection and roguing was made as soon as mosaic symptoms appeared which in northern Maine occurs about July 1 when the plants have emerged two to six inches above the soil. The second inspection followed about ten days later. The third inspection was made when the plants were in blossom and the fourth a few weeks later, before the plants were killed by frost which occurred on a date varying from September 10 to October 1. This fourth inspection is very desirable because one can then best detect all of the late-maturing giant-hill[6] and apical-leafroll plants.[7]

[6] "Giant hill" is a term applied to a late-maturing plant of a certain kind which is readily removed from seed stocks by rigid roguing late in the season. See Folsom, Owen, and Smith, 1931, p. 39 and Fig. 21.

[7] Apical leafroll is a recently described virus disease characterized by a

At the third and fourth roguings, most of the tuber units that showed mosaic were found to be diseased in only part of the unit, varying all the way down to part of a shoot in one hill. It is not possible to say whether such tuber units and hills, showing mosaic in part, represent late manifestation of disease contracted during the preceding season, or early manifestation of disease contracted during the current season. In either instance, such units and hills constitute only a small proportion of the total hills rogued out, being about six per cent. Furthermore, in either instance they probably are less in number than the hills containing the mosaic virus without having shown the symptoms; at least in three successive seasons they comprised only about six per cent of the total tubers having mosaic by the end of the season. However, they should be rogued out even though this requires the careful examination of each row and the observation of all parts of each hill.

The roguing records disclose that most of the mosaic (Figs. 3, 4, and 7, C) and some leafroll plants (Fig. 5) were removed at the first inspection. At the second inspection most of the remaining mosaic and leafroll plants were removed. Spindle tuber (Figs. 6, A and 7, B) is often rather hard to detect before the third roguing. During the third and fourth inspections the remaining spindle-tuber plants were removed as well as plants with incomplete manifestation of infection by mosaic.

EFFECT OF ROGUING ON THE AMOUNT OF DISEASE

The general problem of the effect of roguing on the prevalence of disease is discussed more fully later in this bulletin. Certain conclusions, however, should be given at this time, as they are derived from the results of roguing the Aroostook Farm seed plot. It is noted in Table 1 that, although roguing did not entirely eliminate the virus diseases, it did prevent them from increasing beyond seven per cent. As mentioned later, mild mosaic increased much more in nearby plots that were not rogued. Seed stock that in 1926 had only 3.5 per cent mosaic developed 91 per cent mosaic in two years when unrogued, an absolute increase of 87.5 per cent.

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rolling of the upper leaves and by extreme lateness. See Schultz and Bonde, 1929.

TABLE 1

Aroostook Farm Green Mountain Tuber-Unit Seed Plot

Year	Total number hills	Disease, per cent			Nearest potatoes[1]	
		Mosaic	Leafroll	Spindle tuber	Approximate distance in ft.	Mosaic, per cent
1926	17596	6.6	Trace	4	1000	6.6
1927[2]	14840	5.6	0.5	0.5	200	5.6
1928[3]	23404	1.14	3.5	Trace	1000	6
1929	19904	4.8	0.3	"	1000	4.8
1930	14860	6.5	0.26	0.2	200	6.5
1931[4]	21832	1.8	0.56	0.1	1000	1.8

[1] Variety Green Mountain.
[2] This strain was not continued on the seed plot in 1928 because of the amount of mild mosaic present in 1927. This mosaic was, however, reduced by roguing from 5.6 per cent to 3.5 per cent as shown by a sample of the stock planted in 1928.
[3] The seed planted in 1928 was from southern Maine.
[4] A sample of this stock showed 4.3 per cent mosaic, 0.3% leafroll, and no spindle tuber, in 1932.

Apparently leafroll was easier to control here than mosaic and did not reach one per cent. It is noteworthy that roguing in 1928 reduced leafroll from 3.53 per cent in 1928 to 0.3 per cent in 1929 while this disease was being spread quite generally in commercial potato fields in northern Maine.

Spindle tuber was controlled as effectively as leafroll. Although in 1929 this disease was readily disseminated in some unrogued plots, it did not reach one per cent on the Aroostook Farm seed plot.

The problem of roguing for "giant-hill" control should also be commented on. Giant hill was quite prevalent in the seed plot in 1924 and 1925. These tuber units were readily recognized late in the season by their conspicuously large amounts of green foliage. By carefully removing the tuber units showing these characteristics, giant hill was practically eliminated in one season.

SEED PLOTS ON COMMERCIAL POTATO FARMS AND IN CLEARINGS IN THE WOODS

Although, as indicated previously, the Aroostook Farm seed plot represented average farm conditions with regard to isolation and size, it did not necessarily represent the conditions of many other farms with regard to the percentage of diseases in the nearest potatoes, the number of insect vectors and the distance of the seed plot from diseased potatoes. In order to obtain information on the effect of location on the control of mosaic and other virus diseases, small seed plots were located on farms and in clearings in the woods within ten miles of Aroostook Farm. Inasmuch as it was necessary to plant these seed plots by hand, only several of them were under observation during each season, and each one included only 80 to 500 hills. These small seed plots are designated arbitrarily as seed plots A to G, each letter denoting a farm or a location in the woods.

Unless otherwise indicated, these seed plots were planted and rogued according to the methods used on the Aroostook Farm seed plot. The approximate number and species of insects on the plants, as well as the percentage and type of disease present in the nearest potatoes, were usually recorded. At these inspections a copper-lime dust was applied to the vines by means of a hand duster, in order to control late blight.

The potatoes on seed plots A to G were harvested by hand so that one or two tubers per hill could be reserved for advance testing for virus diseases. These sample tubers were planted at Hastings, Florida, in order to obtain information on the diseases present before planting time in the following season in Maine. If this advance test showed less than three per cent mosaic for any of the lots, this same stock was used for planting on a seed plot in the following season in Maine. If more than three per cent mosaic appeared in a lot in the Florida test, a new lot of seed potatoes reported to have less than three per cent mosaic was substituted for the seed plot in Maine, except in plot E.

SEED PLOT A

In 1927 and 1928, seed plot A was located in a clover field about 400 feet from the nearest potatoes, while in 1929 and 1930

it was located 300 feet from other potatoes. As recorded in Table 2, seed plot A was considerably smaller than the Aroostook Farm plot; its maximum number of hills did not exceed 276.

TABLE 2

Seed plot A[1]

Year	Total hills	Mosaic, per cent	Insects	Nearest potatoes			Disease in seed-plot samples tested in Florida
				Approximate distance in ft.	Variety	Mosaic, per cent	
1927	276	1		420	Green Mountain	2	None in 1928
1928	174	0	Numerous aphids Aug. 5	420	Irish Cobbler[2]	No reading	5% mosaic in 1929
1929	216	0	Few aphids	310	Green Mountain	16	4% mosaic in 1930
1930	120	3	" "	300	"	Trace	1.8% mosaic in 1931

[1] Variety Green Mountain.
[2] Also Green Mountains, with disease content not determined, were planted several hundred feet distant. All commercial Green Mountains are more or less affected by mosaic, while Irish Cobblers (and Spaulding Rose or Rose 4) are immune to it.

Each season a new lot of Green Mountain seed potatoes having a very low percentage of mosaic was planted on this plot, except in 1928 when potatoes which had been propagated on this plot in 1927 were used for seed.

The observations are recorded in Table 2, a study of which discloses that in 1927 and 1930 roguing apparently reduced mosaic, the only virus disease manifested. Inasmuch as no mosaic appeared in this plot in 1928 and 1929, the results from the corresponding samples tested in Florida indicated that this disease was brought into the plot during these seasons. Since mosaic was present in Green Mountains that were not far away, it is possible that the disease came from this source.

SEED PLOT B

Seed plot B was located in a clearing in the woods approximately one and one-half miles from the nearest potatoes. During the three seasons 1928, 1929, and 1930 the potatoes were planted on the same plot.

Each year a new lot of Green Mountains was used. Eighty whole or uncut tubers were planted on this plot in 1928. However, the four-hill tuber-unit method of planting was followed in 1929 and 1930.

As disclosed in Table 3, roguing in 1928 apparently reduced mosaic from 6.25 to 2.7 per cent as shown by the Florida test in 1929. No mosaic was observed in seed plot B in 1929 and 1930. Since deer cropped the upper half of the tops during mid-season in 1929 and 1930, it is possible that mosaic plants may have been missed at inspection in 1929. The record of this stock in Florida in 1930 shows that either this occurred, or the disease entered the plot during that year.

TABLE 3

Seed plot B[1]

Year	Total hills	Mosaic, per cent	Disease in seed-plot samples tested in following season in Florida
1928	80	6.25	2.7% mosaic in 1929
1929	80	0	1.7% mosaic in 1930
1930	84	0	None in 1931

[1] Variety Green Mountain, with few aphids present and the nearest potatoes about 7900 feet distant, of the Green Mountain variety, and about 50 per cent mosaic.

SEED PLOT C

Seed plot C was located in a clearing in the woods about 1100 feet from the nearest potatoes. As in seed plot B, no rotation was followed; the potatoes were planted on the same site or plot from 1927 to 1931.

Two Green Mountain seedlings, originated from seed which was collected from a commercial strain in 1926, were planted on this plot for the first time in 1928. The same seedlings were grown on plot C until 1931 when seedling number 2 was excluded because it produced fewer tubers than seedling number 1.

As the results recorded in Table 4 show, the seedling Green Mountains have not manifested mosaic or any other virus disease

while they were grown on seed plot C from 1928 to 1931. Inoculations of these seedlings elsewhere with mosaic have shown that they manifest this disease like the commercial Green Mountain. Isolation of these seedlings from the beginning apparently maintained their disease-free condition during four seasons.

TABLE 4

Seed plot C

Year	Variety	No. of hills	Insects	Mosaic, per cent in nearest potatoes[2]	Disease in seed-plot samples tested in following season in Florida
1928	Green Mountain seedling No. 1[3]	10	No aphids. Few flea beetles and frog hoppers		0
1929	"	52	Few flea beetles and tarnished plant bugs. No aphids	50±	0
1930	"	84	Few aphids and flea beetles	20	0
1931	"	156	Few aphids. Many flea beetles	30	—[4]
1928	Green Mountain seedling No. 2[3]	5	As for seedling No. 1		0
1929	"	42	"	50±	0
1930	"	80	"	20	0

[1] None mosaic in any year.
[2] Variety Green Mountain, about 1100 feet distant.
[3] Each seedling in 1927, consisted of one hill grown in a plot located in the woods but not located here.
[4] About 10 per cent mosaic in 1932 on Aroostook Farm.

SEED PLOT D

From 1926 to 1929, seed plot D was located on a peat bog about 800 feet from the nearest potatoes. During 1930 and 1931, this plot was located on Caribou loam soil in a clearing in the woods about 500 to 800 feet from the nearest potatoes.

Seed plot D was planted with the same strain of the Bliss Triumph variety from 1926 to 1931. The seed potatoes were selected from the row lots which, in the samples tested in Florida, showed the lowest percentage of disease.

As disclosed in Table 5, from 1926 to 1929 there was no mosaic or any other virus disease in seed plot D, although representative samples, consisting of one tuber per hill, which were gathered in 1927 to 1929 and planted in Florida, developed a low percentage

TABLE 5

Seed plot D[1]

Year	Total hills	Mosaic, per cent	Insects	Nearest potatoes			Disease in seed-plot samples tested in following season in Florida
				Approximate distance in ft.	Variety	Mosaic, per cent	
1926	240	0	Few aphids	200	Rose 4[2]	0	—
1927	260	0	Few aphids Many flea beetles	200	Irish Cobbler[2]	0	1.2% mosaic in 1928
1928	319	0	Many aphids	800	Rose 4[2]	0	0.3% mosaic in 1929
1929	388	0	Few aphids	800	Green Mountain	2	3.2% mosaic in 1930
1930	240	1.7	" "	800	"	5	2.1% mosaic in 1931
1931	272	2.9	" "	800	"	10	—

[1] Variety Bliss Triumph.
[2] Immune to mild mosaic.

of mosaic plants. These results indicate either that mosaic entered the plot too late in the current season to be manifested on the infected plants and was limited to the Florida sample, or that mosaic symptoms were masked in Maine. This experiment with the Bliss Triumph variety, which manifests mosaic almost as clearly and contracts this disease as well as the Green Mountain variety, shows that it may be propagated practically free from mosaic for several seasons in northern Maine.

SEED PLOT E

Seed plot E was located in 1926 in a clover field about 200 feet from the nearest potatoes. In 1927 and 1928, this plot was located in a field about 2600 feet from the location of this plot in 1926. The

nearest field in 1926 had 5% mosaic and in 1928 the nearest field had about 50% mosaic.

The Green Mountain seed potatoes planted on plot E in 1926 were grown on the Aroostook Farm seed plot in 1925. This same strain of potatoes was propagated on seed plot E in 1927 and 1928.

As recorded in Table 6, seven per cent was rogued for mosaic control from plot E in 1926. However, 15 and 12 per cent of the plants, respectively, in 1927 and 1928, were found to be mosaic in plot E, while the same stock as grown on the Aroostook Farm seed plot from 1926 to 1928 showed only 5.6 and 3.5 per cent of the tops to be mosaic, respectively, in 1927 and 1928. Although these results indicate that mosaic was controlled better on the large seed plot than on the small one, it is quite probable that the better isolation of the large one in 1926 influenced the results.

TABLE 6

Seed plot E[1]

Year	Total hills	Mosaic, per cent	Insects	Nearest potatoes			Disease in seed-plot samples tested in following season in Florida
				Approximate distance in ft.	Variety	Mosaic, per cent	
1926	400	7	Few aphids. Many flea beetles	200	Green Mountain	5	—
1927	474	15	Many aphids and flea beetles	300	Rose 4[2]	0	9% mosaic in 1928
1928	300	12	Many aphids and flea beetles	200	Green Mountain	50±	18% mosaic in 1929

[1] Variety Green Mountain.
[2] Immune to mild mosaic.

SEED PLOT F

Seed plot F was located in a clearing in the woods about 500 feet from the nearest potatoes. Seed potatoes of the Green Mountain variety, grown on plot F in 1929, were planted on the same plot in 1930.

As Table 7 discloses, no disease was observed in this plot in 1929. However, sample lots planted in Florida in 1930, manifested

TABLE 7

Seed plot F[1]

Year	Mosaic, per cent	Insects	Nearest potatoes[2]		Disease in seed-plot samples tested in following season in Florida
			Variety	Mosaic, per cent	
1929	0	Flea beetles. Few aphids	Bliss Triumph	10	0.1% mosaic and 0.1% leafroll in 1930
1930	0[3]	Few aphids and flea beetles	Green Mountain	5	4% leafroll in 1931

[1] Variety Green Mountain, total hills 84 each year.
[2] About 500 feet distant.
[3] Trace of primary leafroll.

0.1 per cent mosaic and 0.1 per cent leafroll. During the last inspection in August, 1930, a few plants showed leafroll symptoms only in the apical leaves which suggested primary or current-season infection by leafroll. Sample lots from this plot developed four per cent leafroll in the Florida test in 1931. Since no leafroll was observed in the potatoes in the nearest field, it is possible that this disease may have been harbored by some neighboring weed host or brought in from another more distant field. No leafroll appeared in the three other plots (B, C, and D) which were located in clearings in the woods.

SEED PLOT G

Seed plot G was located in a clover field about 400 feet from the nearest potatoes in 1930, and approximately 800 feet from the nearest potato field in 1931. It was planted in 1930 with the same strain of Green Mountains as was planted on seed plot A. In 1931 a new lot of seed potatoes was used.

Table 8 shows that 4.4 per cent of the plants were rogued for mosaic from plot G in 1930. Sample lots propagated in Florida in 1931, developed 2.7 per cent mosaic which indicates that the number of diseased plants in this plot was reduced by roguing. On the other hand, a disease-free stock apparently acquired the disease here in 1931.

TABLE 8

Seed plot G[1]

Year	Total hills	Mosaic, per cent	Insects	Nearest potatoes			Disease in seed-plot samples tested in following season in Florida
				Approximate distance in ft.	Variety	Mosaic, per cent	
1930	180	4.4	Few aphids	400	Green Mountain	25	2.7% in 1931
1931	200	0	——	800	Irish Cobbler[2]	0	——[3]

[1] Variety Green Mountain.
[2] Green Mountains, with disease readings not taken, were located at a greater distance than these Irish Cobblers, which are immune to mild mosaic.
[3] About 4.4 per cent mosaic in 1932 on Aroostook Farm.

CONCLUSIONS ON SEED PLOTS A TO G

In seed plots A to G (see Table 9) we have 24 chances to compare the percentage of mosaic of one year with that of the next,

TABLE 9

Summary of results with seed plots A to G[1]

Plot		A	B	C	D	E	F	G	A-G, totals			
									E[2]	I	RA	D
1926		------	--------	--------	RA	I	--------	------	------	1	1	------
1927		D	--------	(RA)[3]	E	D	--------	------	1	------	1	2
1928		E	(D)	(RA)	E	I	--------	------	2	1	1	1
1929		E	(E)	(RA)	E	------	(E)	------	4	------	1	------
1930		D	(RA)	(RA)	(I)	------	(RA)	D	------	1	3	2
1931		------	--------	(E)	--------	------	--------	E	2	------	------	------
1926-31 totals	E	2	1	1	3	------	1	1	9	------	------	------
	I	------	--------	--------	1	2	--------	------	------	3	------	------
	RA	------	1	4	1	------	1	------	------	------	7	------
	D	2	1	--------	--------	1	--------	1	------	------	------	5
In clearings		------	--------	--------	--------	------	--------	------	3	1	6	1
Not in clearings		------	--------	--------	--------	------	--------	------	6	2	1	4

[1] From Tables 2 to 8 and pp. 8-14 of the text.
[2] Mosaic entered (E), increased (I), remained absent (RA), or decreased (D).
[3] In clearing in woods, shown by ( ).

in a given seed stock. There was an entrance of mosaic into a healthy stock in nine instances, an increase in the percentage of mosaic in three, a decrease in five, and a maintenance of freedom from mosaic in seven. In every seed plot there were instances of both entrance or increase on the one hand, and decrease or maintained healthiness on the other hand. Thus no seed plot was consistent. There was no more consistency than this for the group of seed plots of any one year, except 1931 when these two plots were entered by mosaic. Consequently it is necessary to conclude that at present it can not be predicted in what place a given degree of success will be attained in such seed plots in the control of mosaic. Neither is there yet any way of telling during the growing season what degree of success has been attained in a given plot, even if knowing the relative abundance of insects in the seed plot or the distance of isolation from other potatoes. Location in clearings in the woods gave favorable results in 64 per cent of the instances as compared with 50 per cent for all plots and 38 per cent for those in open fields.

CONTROL OF LEAFROLL AND SPINDLE TUBER ON SEED PLOTS

Experience in attempts to control leafroll and spindle tuber on isolated tuber-unit seed plots in northern Maine has shown that these diseases are easier to control there than mosaic. Observations indicate that in this section of Maine, in some seasons at least, leafroll and spindle tuber spread less generally than mosaic, which difference apparently influences the relative ease of control of these diseases.

One strain of Irish Cobblers, which was planted on an isolated tuber-unit seed plot and was rogued by us in 1923 when 22 per cent of spindle-tuber plants were removed, was propagated on seed plots until 1931. Since 1924 this strain of Irish Cobblers manifested less than two per cent of spindle tuber. In 1931 no spindle tuber appeared in this strain. Reports from some of the commercial growers, who during several seasons have conducted isolated tuber-unit seed plots with Spaulding Rose and Irish Cobblers, have shown that they controlled spindle tuber and leafroll.

THE EFFECT OF ROGUING TUBER-UNIT SEED PLOTS ON YIELD

Although it has generally been recommended that farmers conduct tuber-unit seed plots, very little information has been available to show the actual benefits that can be derived from such a practice. Folsom and Schultz (1924) and Folsom, Schultz, and Bonde (1926) have given information regarding the natural spread and the effect on yield of the different virus diseases under Maine conditions. Spindle tuber and mild mosaic may reduce the yield 8 to 40 per cent. Rugose mosaic was especially detrimental when present and reduced the yield rate 50 per cent below that secured from healthy stocks grown under the same field conditions. Leafroll probably reduces the yield at least as much as does rugose mosaic.

These tests have shown the importance of disease in potato production. They, however, do not show fully the value of a seed plot and the benefits that may be expected from its use under practical farm conditions, because they do not show the rate of increase in disease.

From 1928 to 1931, a series of plots was studied on Aroostook Farm for the purpose of contributing data bearing on the economic value of the rogued tuber-unit seed plot. It was planned to study the effect of roguing on the percentage of disease and, through that, its indirect effect upon yield.[8] Throughout these comparisons, seed potatoes from the same original strain of Green Mountains were used. For these tests one lot of seed potatoes was taken each season from seed-plot stock that had been rogued of disease the previous year. These were compared with other lots that had been grown for one, two, three, and four years respectively, unrogued under commercial field conditions.

Every precaution was taken to make the tests, and the different lots in any one test, comparable. The seed potatoes for all the lots of any one test were stored and treated in the same manner prior to planting. The plots were planted and sprayed similarly through

[8] The direct effect of roguing upon yield in tuber-unit seed plots depends upon the size of the tuber units, the distance between them, etc. (See Folsom, Owen, and Smith, 1931, pp. 17, 27, and 71.) Even when rogued hills mean a total loss in yield at the time, this factor is insignificant in comparison with others such as cost of labor for roguing, seasonal variation in yield rate, prices, etc.

the tests. Yield rates were determined from 100-foot one-row plots that were replicated from six to twelve times.

The indirect effect of roguing on yield from 1928 to 1931, is recorded in Table 10. The diseases present in the test plots are

TABLE 10

The effect of roguing on yield rate[1]

Source of seed stock	Barrels per acre[2]			
	1928	1929	1930	1931
Rogued previous year	142	147	132	183
Unrogued the preceding year	127	147	121	180
Unrogued two preceding years	107	129	109	159
Unrogued three preceding years	----------	118	117	121
Unrogued four preceding years	----------	----------	107	----------

[1] See Table 11 for the diseases present in these lots.
[2] A "barrel" is 2¾ bushels or 165 pounds or 11 pecks.

given in Table 11. It is obvious from these data that increase of disease in the absence of roguing can generally be expected to decrease the size of the crop after at least two years. In 1929, 24 per cent of mild mosaic had no effect upon the yield rate. In 1928 and 1931, seed stocks containing 20 and 18.6 per cent disease, respectively, did not yield significantly less than relatively healthy seed stock. These facts show that it may be safe for growers to plant seed potatoes which are one year removed from the seed plot, provided the fields are grown for table stock with yield the only consideration.

Goss and Werner (1928, p. 151) make the following statement regarding the reduction in yield resulting from disease in the Bliss Triumph potato variety when grown in the southern states: "In our own tests of Nebraska seed in the southern states and in the published results of various southern stations, there is no evidence of a reduction in yield in proportion to percentages of mosaic up to about 20 per cent." They suggest (p. 152) that it would be advisable to have two sets of standards, one for production of foundation stock and another for seed used by the table-stock grower.

TABLE 11[1]

The effect of roguing on the amount of virus disease in Green Mountain seed stock

Source of seed stock	1928			1929			1930			1931		
	Mild mosaic	Spindle tuber	Leaf-roll	Mild mosaic	Spindle tuber	Leaf-roll	Mild mosaic	Spindle tuber	Leaf-roll	Mild mosaic	Spindle tuber	Leaf-roll
Rogued previous year in tuber-unit seed plot	3.5	Trace	Trace	2	Trace	Trace	7	0.5	None	2.6	0.6	0.3
Not rogued one year	20	"	"	24	"	"	81	None	"	18.6	0.3	0.3
Not rogued two years	91	"	"	73	"	"	95	1.0	"	98	1.0	4.0
Not rogued three years	------	------	------	97	"	"	99	None	"	100	12.0	0
Not rogued four years	------	------	------	------	------	------	100	"	"	------	------	------

[1] See Table 10 for the yield rates of these lots.

Likewise in Maine, seed stock intended for table-stock production would permit a higher tolerance of mild mosaic than that intended for foundation stock.

Although the presence of mild mosaic in 20 per cent of the plants may not reduce the yield significantly, the data in Table 11 show that if potatoes now having 20 per cent of mild mosaic should be planted the following season, mosaic would be likely to develop in 70 to 98 per cent of the plants. Taking from Tables 10 and 11 the nine instances where 73 to 100 per cent of the plants were mosaic, the yield rates were reduced eight to 34 per cent, the average of the percentages of loss being 18 per cent. Considered in another way, these nine instances give an average reduction of 27 barrels per acre which is 18 per cent of the average yield rate (for the nine instances) of 148 barrels for healthy stock. At this rate, while a grower who secured rogued or similar seed every second year could keep his yield at the maximum, roguing only every third year would result in a loss of 18 per cent every third year or an average annual loss of six per cent, with a corresponding estimated loss of nine to 15 per cent for roguing only every fourth to twelfth years.

Assume now that a Green Mountain table-stock grower uses ten barrels of field-run potatoes to plant an acre, gets at least 100 barrels an acre to sell, and wants to avoid the losses from mosaic to be expected when the higher percentages of mosaic are present. Such a grower has several policies from which to choose. These are briefly as follows, for each ten acres of table stock to be grown:

(1) Each year, use one bbl. of foundation stock (seed which will be good enough to certify or to rogue) to plant an isolated tuber-unit seed plot of 1/10 acre, getting ten bbls. of rogued seed. Each year, plant the ten bbls. of rogued seed in a one-acre isolated unrogued seed plot, getting 100 bbls. of second-year seed. Each year, plant the 100 bbls. of second-year seed in a ten-acre table-stock field, getting 1,000 bbls. to sell.

(2) Every alternate year, use 10 bbls. of foundation stock to plant a one-acre isolated tuber-unit seed plot getting 100 bbls. of rogued seed to plant next year in a ten-acre field. From this field sell 900 bbls. and keep 100 bbls. to plant the following year as second-year seed on a ten-acre field yielding 1,000 bbls. to sell as table stock.

(3) Every alternate year use 100 bbls. of rogued seed or of the best certified seed to plant a ten-acre field, getting 900 bbls. to sell and 100 bbls. to plant next year as second-year seed in a ten-acre field yielding 1,000 bbls. to sell as table stock.

(4) Each year, use 100 bbls. of certified seed or of the best non-certified seed to plant ten acres of table stock producing 1,000 bbls. to sell as table stock.

The four preceding methods are concerned with the grower of table stock. The would-be grower of certified seed stock or of foundation stock has a more difficult problem in so far as the control of mosaic is concerned. On this, further work is required beyond that reported in this bulletin.

The effect of roguing on foliage symptoms and on the general appearance of the potato fields and plots is readily seen in Figures 8, 9, and 10. It may be noted that the seed potatoes which were not rogued for two and three seasons and which were practically 100 per cent diseased died earlier than the adjacent plots planted either with seed directly from the seed plot or with stock that had been unrogued for only one season.

In 1931, seed stock not rogued for three consecutive seasons yielded 62 barrels per acre less than seed from the seed plot. This large reduction was apparently due in part to an increase in the amount of spindle tuber and leafroll which in combination with mild mosaic and other virus diseases results in an inferior crop production.

These results show the reduction in yield that occurred in Aroostook County where the conditions are ideal for potato culture. According to unpublished data of the writers, the presence of virus diseases has a more serious effect on yield in the more southern potato regions. On Long Island, New York, for example, a given percentage of disease may be expected to reduce the yield about 15 per cent more, relatively, than the same amount of disease will in the same stocks grown under Aroostook conditions.

REASONS FOR THE EFFECT OF ROGUING ON THE AMOUNT OF VIRUS DISEASES

The preceding sections have shown that virus-disease increase occurs commonly in northern Maine, especially in unrogued stocks, and that such increase will reduce yields when it has involved more than 70 per cent of the stock. From the data in Table 11 it is seen that only mild mosaic spreads here with alarming rapidity when potatoes are unrogued. When Green Mountains were grown unrogued for two seasons under commercial field conditions, from 73 to 98 per cent of the plants were affected with mild mosaic and after three years practically the whole crop was thus affected. Green Mountain stock having one to two per cent of mild mosaic and left unrogued for one season can ordinarily be expected to contain from 18 to 25 per cent of mild mosaic in the following season. In some seasons, however, the spread of mild mosaic may be considerably greater than this amount. Seed potatoes containing two per cent mild mosaic in 1929 gave a progeny in 1930 that was diseased to the extent of 81 per cent. It is to be noted that the percentage of mild mosaic found in stocks coming directly from the rogued seed plot varied from as little as two per cent in 1929 to seven per cent in 1930.

The results recorded in these comparisons are wholly in accord with studies on disease dissemination conducted in a separate set of experiments that are not included here.

It is proposed here to offer some reasons why mild mosaic spreads so much more than the other virus diseases, why the spread of mild mosaic varies, and why its spread is checked considerably by roguing.

The reason why leafroll has not been readily disseminated in our tests on Aroostook Farm is of great interest and deserving of some consideration. The peach or spinach aphid, *Myzus persicae* Sulz., is considered to be especially suited, according to Smith (1931), for the transmission of leafroll. In Aroostook County this aphid species is rarely abundant.[9] Insect studies have revealed that *M. persicae* becomes noticeable on potatoes only late in the season after the other potato aphids have largely migrated to their primary host plants and at a time when the fall frosts are about to kill the potato fields. At that time the early varieties have generally matured and the disease transferred by aphids to the late varieties will in many cases not have had sufficient lapse of time in which to infect the tubers. Therefore the relative absence of the spinach aphid and its late seasonal appearance seem to be the chief reasons that leafroll has not spread extensively in our roguing tests conducted in Aroostook County in northern Maine.

Murphy and McKay (1929) and Smith (1931) have reported that the foxglove aphid, *Myzus pseudosolani* Theob., is capable of transmitting leafroll. Smith (1931), however, states that this aphid does not disseminate leafroll as readily as does the peach or spinach aphid. On Aroostook Farm *M. pseudosolani* has been found rather abundantly on potatoes in some seasons and appears to be more numerous than *M. persicae*. Its rôle in the dissemination of the potato virus diseases has not been determined. The rose or potato aphid, *Macrosiphum gei* Koch (= *M. solanifolii* Ashm.), and the buckthorn aphid, *Aphis rhamni* Boyer (= *A. solanina* Pass. and *A. abbreviata* Patch), are the most abundant aphid species in the potato fields in the vicinity of Aroostook Farm. These aphids are present in considerable numbers every year. Smith (1931), in England, however, found that these two species apparently are not efficient vectors of leafroll. In his tests the rose aphid gave negative results with leafroll for four consecutive years and

[9] The authors wish to thank Dr. Edith M. Patch of the Maine Agricultural Experiment Station for frequent identification of aphids.

the buckthorn aphid did not transmit leafroll for two consecutive years.

The slow increase of spindle tuber in comparison with mild mosaic in Aroostook County is also of interest. According to the data in Table 10, spindle tuber was not an important factor in these tests. Seed potatoes having a trace of spindle tuber and left unrogued for four consecutive seasons accumulated only 12 per cent of this disease. In the rogued seed plots we have rarely found more than a trace of spindle tuber.

Werner (1925) found that spindle tuber is the cause of most of the degeneration in seed potatoes in Nebraska. It is apparent that either the climate or some other general condition in Aroostook County is unfavorable to the rapid dissemination of spindle tuber. Probably efficient insect vectors are not abundant.

Schultz and Folsom (1923, pp. 50, 51, 57, 58, and 74; 1925, pp. 509 and 512) transmitted spindle tuber by means of the rose or potato aphid, *Macrosiphum solanifolii* Ashmead. The rose or potato aphid and the buckthorn aphid, the two dominating aphid species on potatoes in this section, have, however, often given negative results in tests with spindle tuber on Aroostook Farm (unpublished data) indicating that they may not be good vectors of this disease.

Goss (1928) has reported that grasshoppers, *Melanoplus spp.*, may transmit spindle tuber. Goss (1930) has also shown that flea beetles, *Epitrix cucumeris* and *Systena elongata*, the leaf beetle, *Disonycha triangularis*, the tarnished plant bug, *Lygus pratensis*, and the Colorado potato beetle, *Leptinotarsa decemlineata*, also are vectors of spindle tuber.

The writers have successfully transmitted spindle tuber with the flea beetle, *Epitrix cucumeris*, and with the larvae of the Colorado potato beetle (unpublished results). These biting insects are, however, not generally abundant although they are present to some extent each season. Their scarcity and that of grasshoppers probably explain the slowness of spread of spindle tuber in northern Maine.

It is the writers' opinion that most of the spindle tuber in seed stock grown in Aroostook County is due to the lack of thorough roguing. Each season occasional diseased tuber units remain unnoticed during roguing and thus the disease perpetuates itself from season to season.

It is, therefore, realized that spindle tuber is disseminated by means of insects in Aroostook County, but according to the writers' observations this disease is not spread as extensively as is generally assumed and can be readily controlled by the use of properly conducted tuber-unit seed plots.

Schultz and Folsom (1923, p. 50, and 1925, pp. 509 and 518, have shown that both the rose or potato aphid and the buckthorn aphid can transmit potato mild mosaic, and (Schultz and Folsom, 1923, p. 83) that the spinach aphid can transmit mosaic. The rapid spread of mild mosaic can therefore be attributed to the presence of these aphids. For example, the great increase of mild mosaic from two per cent in 1929 to 81 per cent in 1930 in unrogued stock (Table 11), and from two per cent in 1929 to seven per cent in 1930 in rogued stock (Table 11), is correlated with an extreme abundance of aphids in 1929.

WHY SHOULD SEED PLOTS BE PLANTED IN TUBER UNITS?

All seed plots should be planted by the tuber-unit method if the best results are to be obtained. According to this method all of the seed pieces from each tuber are grouped together in the row in consecutive or adjacent hills. Generally it is advisable to cut each tuber into four seed pieces and to leave a skip or vacant place between the last seed piece from each tuber and the first seed piece of the next tuber.

The tuber-unit method is recommended because of the following advantages: (1) Diseased hills are more conspicuous and easier to detect if they are grouped in the row. (2) Grouped hills are more easily removed than scattered hills. (3) Fewer centers or sources exist for the dissemination of disease within the field because of the grouping of the hills that are planted from each diseased tuber. (4) Late-growing diseased hills that do not yet show symptoms can be judged by their more advanced sister hills in the same tuber unit, and therefore can be removed sooner and more easily than when each hill is passed upon individually as is necessary in other kinds of seed plots. (5) Hills that are only partly infected, providing other hills of the same tuber unit show the disease, are not as easily missed if all of the hills from a tuber have been

grouped. Sometimes only one hill of a tuber unit may show the disease completely, in which case all of the hills from the same tuber are removed, although the disease is not yet manifested throughout and may never be.

HOW TO PLANT TUBER-UNIT SEED PLOTS

The planting of a tuber-unit seed plot is often considered tedious and laborious and this is one of the reasons why many growers prefer not to raise their own seed stock by this method. There are three general methods that are recommended for planting a tuber-unit seed plot, all of which might have a place on different farms. These methods will be considered briefly.

(1) *Hand Planting.* By this method the furrow is generally opened with the potato planter. The covering discs are removed to prevent covering the furrow before the seed pieces have been planted. On Aroostook Farm it has been found advisable to drag a heavy chain in the furrow behind the planter in order to mix the fertilizer and soil enough to prevent the fertilizer from coming into contact with the freshly cut surfaces of the seed pieces. The tubers are carried in a pail or basket and are cut by hand in the field, and the seed pieces from each tuber are dropped in succession in the row. A vacant space is left after each tuber, making the plants from the respective tubers stand out as obvious units. The rows after planting are covered with a single-row disc cultivator.

This method is rather slow, laborious, and expensive. Some growers, however, prefer this method to others and claim that more careful attention can thus be given to the planting and spacing of the individual seed pieces.

(2) *Commercial Automatic Cutter and Planter.* On Aroostook Farm a commercial tuber-unit cutting and planting machine has been used with fairly good success. (Bonde and Folsom, 1927, and Folsom and Bonde, 1928.) The machine requires quite critical adjustment in order to space the tuber units uniformly and to prevent mixing and piling up of the seed pieces. Harrington (1927) found the machine fairly satisfactory only for the round-type potato varieties, such as the Bliss Triumph.

This automatic cutter and planter, although not entirely satisfactory, has certain advantages and might be used profitably by

some growers. The machine is a labor-saving device which eliminates hand cutting. On smooth flat land and with the Irish Cobbler and Bliss Triumph varieties, or with Green Mountains selected for proper shortness, growers may expect the machine to give fairly satisfactory results.

(3) *Tuber-unit Two-man Planter.* In 1931, a two-man Iron Age commercial planting machine was employed on Aroostook Farm for tuber-unit planting. (Fig. 2.) This method of planting by tuber units has been previously described by Harrington (1928) and by Bateman (1927).

The standard Iron Age potato-planting machine can readily be converted for tuber-unit planting on purchasing the tuber-unit feed wheel which is easy to attach. It is also a relatively simple procedure to stop off two opposite pockets in the ten-pocket feed wheel of the standard equipment and thus have two four-hill tuber units separated by blank spaces.

The seed is cut by hand and the four seed pieces from each tuber are put into tin cans or other suitable receptacles carried on the planter. Harrington (1928) constructed a special tray which fits over the hopper of the machine with compartments for holding the cut seed pieces. The frame is easily put in place or removed from the machine. The practice has been to have two or more removable frames. One man may cut and fill the cans in one frame while the planter machine is in operation and using the other. On Aroostook Farm, the seed tubers were carried on the planting machine in wooden flats with compartments (Figs. 1 and 2). Each compartment contained the seed pieces of a single tuber.

Instead of using trays and tin cans, some growers may find it more practical to use pint raspberry boxes or small paper bags. The use of small (one-pound) paper bags is inexpensive and desirable for growers who wish to plant only a small acreage. The paper-bag method is also the most desirable one if the grower wishes to cut a quantity of seed in advance. The practice of cutting the seed pieces in advance and storing them in small separate bags would have the added advantage of allowing the seed pieces to become thoroughly dry before planting, which is a factor in the elimination of spindle tuber by knife transmission and by seed-piece contact. It is also a factor in controlling blackleg in early-cut seed.

The two-man Iron Age tuber-unit planter has certain advantages. Planting by this method is considerably more rapid and

economical than planting by hand, especially if relatively large seed plots are to be planted. The planter also insures a uniform depth of planting and uniform spacing of the seed pieces.

Cutting the seed tubers by hand has the advantage that each individual tuber can be rather critically examined for symptoms of spindle tuber and for net necrosis which is a symptom of recent leafroll infection. Since experiments have shown that spindle tuber can be transmitted with the cutting knife if the freshly cut seed pieces are planted soon after cutting, it is advisable to disinfect the knife in formaldehyde unless the seed tubers are known to be free from spindle tuber.

PRECAUTIONS IN ROGUING TUBER-UNIT SEED PLOTS

During the seed-plot roguing operations certain precautions should be observed. The writers have found it advisable to place all of the rogued plants immediately in heavy canvas bags that are carried to the ends of the rows and emptied into barrels. This prevents aphids from escaping from the rogued tops to healthy plants. These barrels are hauled away on the day when the tops are rogued and the diseased tops, tubers and seed pieces are deposited at least one mile from the plot. Care should be taken to remove from the plot all the seed pieces of the diseased hills as well as the diseased tops because the seed pieces may sprout again and produce plants which serve as further sources of disease dissemination. The new tubers should also be removed even if too small to be picked up at digging time, because such tubers may live over to the next year in the seed plots and produce volunteer plants. On Aroostook Farm volunteer plants have come up and produced tubers for three consecutive years without these tubers being destroyed by cold during the winters.

Some growers make a practice of leaving the rogued plants to dry and wilt before they are gathered and destroyed. This practice should be especially discouraged because it may result in more disease dissemination than if the plants had not been removed. The insect vectors leave the wilted plants and become widely scattered, establishing themselves on the healthy plants in the seed plot. This reduces the efficiency of the roguing.

All the plants that are abnormal should be removed at once. Many growers remove only the tuber units that are obviously diseased and leave all those that are doubtful for later observation. In this manner many diseased and undesirable tuber units remain unrogued and are allowed to perpetuate themselves, or remain longer than necessary as sources of spread of disease. It is the safest plan to remove all of the abnormal plants when noted and not leave them for later observation.

Finally, only one row should be inspected at a time. Otherwise individual diseased hills in a unit, or even an entirely diseased four-hill unit, sometimes is missed.

CONTROL OF BLACKLEG BY TUBER-UNIT SEED PLOTS

Thorough roguing, careful seed selection and seed treatment are often recommended as means of controlling blackleg in potatoes. It is the writers' opinion that roguing, seed selection, and seed disinfection all help to reduce the amount of blackleg. The method of handling the seed after it has been cut seems, however, to be of far greater importance. The blackleg disease has never been observed by the writers in seed planted immediately after cutting while carefully rogued seed-plot stock that has not shown evidence of blackleg infection for several seasons may produce this disease in abundance under certain conditions.

For example, in 1928, blackleg was present to the extent of 0.1 per cent in a limited portion of the Aroostook Farm seed plot. The disease was present only in four rows in which the seed stock had been treated in a special manner. That is, large seed tubers had been halved and allowed to stand in open barrels for ten days before being planted. During this period some of the tubers developed a bacterial spotting on their cut surfaces, which resulted in the appearance of the blackleg disease in the plants.

It is also worth mentioning that carefully rogued seed-plot stock of another strain developed blackleg in 21 per cent when planted in a commercial field. This seed stock had never shown any blackleg when grown in the tuber-unit seed plot where only freshly cut seed had been planted. In 1928, the amount of blackleg infection in the commercial field varied from none to 21 per cent

depending on the condition of the seed when planted.

In conclusion, the blackleg epidemics that have sometimes occurred in Aroostook County cannot all be explained on the basis of a lack of roguing or improper seed selection, and have not been eliminated by seed disinfection. On the other hand, to the extent that tuber-unit seed plots are planted with freshly cut tubers they will reduce the trouble that is caused by blackleg.

SUMMARY

(1) Freedom from virus diseases in seed potatoes is important to potato growers of Aroostook County, in northern Maine. The spreading of these diseases by insects is reduced by the isolation and roguing of tuber-unit seed plots. In this region, mild mosaic has been more difficult to control than leafroll and spindle tuber. Only one seed stock should be planted on any seed plot.

(2) A Green Mountain seed plot of one to two acres on Aroostook Farm was considered rather typical though not ideal. Six years of experimental roguing here prevented an increase of virus diseases beyond seven per cent, in contrast with an increase to 91 per cent in two years in a nearby unrogued field. Leafroll and spindle tuber were controlled much more effectively by this method than mild mosaic, and giant hill was easily eliminated. Several methods of planting tuber units proved to be suitable. At least four roguings were found to be desirable.

(3) Several locations, both on commercial potato farms and in clearings in the woods, were tested with small seed plots of from one to 500 hills. Bliss Triumphs were planted in one location, seedlings of Green Mountain parentage in another, and Green Mountains in the remainder. In 12 instances there was an increase in mosaic from one year to the next and in 12 other instances there was either a decrease or a maintenance of freedom from the disease. In these respects no plot was consistent throughout the two to five years in which it was tested. Also, no one season gave similar results from all plots. Location of the seed plots in clearings in the woods favored control somewhat. Insect records, the distance of isolation from other potatoes, and other data had no value in predicting the degree of success which was being obtained during the

season in the control of mosaic. The first information about this was secured from samples planted during the winter in Florida.

(4) In the absence of roguing, mild mosaic had increased to 70 per cent or over in about two years, whereupon it reduced the yield about 18 per cent or 27 barrels an acre. A grower can choose between several practical policies in regard to seed plots, if he wishes merely to obtain the maximum yields.

(5) It is thought that the causes of seasonal differences in the increase of mild mosaic are largely entomological, and likewise the difference between the rate of increase of mild mosaic and that of leafroll and spindle tuber. That is, insects of different kinds are unlike in their ability to transmit any one disease, and the efficient insect vectors of mild mosaic vary in abundance from season to season. Furthermore, insects of the same kind do not transmit different diseases similarly, and the efficient vectors of mild mosaic are generally more numerous in this region than those of leafroll and spindle tuber.

(6) Tuber-unit planting has the advantages of quicker detection and easier and more nearly complete removal of diseased hills, decreasing the number of infection centers, earlier roguing of late-growing diseased hills, and decreasing the chance of overlooking partly diseased hills.

(7) Three general methods are recommended for planting by tuber units, namely, by hand, with a commercial automatic cutter and planter, and with a two-man planter.

(8) For the greatest efficiency, roguing requires complete and immediate removal of all diseased and suspected plants, only one row being examined at a time.

(9) The control of blackleg is easier and more nearly complete through planting freshly cut seed, as is usually done in tuber-unit planting, than through roguing, seed selection, and seed treatment altogether.

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FIG. 3. Green Mountain leaf showing the characteristic symptoms of mild mosaic. Note the mottling and slight wrinkling. See also Fig. 4.

Fig. 4. On left, Green Mountain leaf showing the characteristic symptoms of mild mosaic. (See also Fig. 3). On right, Green Mountain leaflet apparently free of mild mosaic.

FIG. 5. Green Mountain hills, healthy at left and leafroll in middle and at right. Note rolled leaves; first symptoms of leafroll appear at base of plant, while later every leaf may be rolled. Entire plant is dwarfed and more rigid than healthy plants.

FIG. 6. Green Mountain hills, (A) spindle tuber and (B) healthy. Note that the spindle-tuber plant has a more erect, open, and "staring" habit than that of the healthy plant.

FIG. 7. Green Mountains. (A) and (D), one row each of healthy; (B), spindle-tuber; (C) mild mosaic. Note that the habit of the spindle-tuber tops is less spreading and more staring or erect than that of the healthy or mild-mosaic, and that the mild-mosaic tops are more dwarfed and their leaves are more wrinkled than those of healthy plants.

FIG. 9. Effect of roguing on mild mosaic in Green Mountains. Photographed September 11, 1931. Same place as for Fig. 8 except photographed from the opposite direction. On left, with only 2.6 per cent mild mosaic tops, grown from seed potatoes which in 1930 were propagated on Aroostook Farm seed plot. On right, same strain of potatoes as at left but not rogued for two and three seasons; only a trace of healthy plants left. As shown here, mosaic plants die earlier than healthy tops which materially contributes towards reducing the yield rate.

FIG. 10. Field of Green Mountains on Aroostook Farm, 1932. Source of seed potatoes was Aroostook Farm tuber-unit seed plot where this strain of Green Mountains has been propagated for five consecutive seasons. Diseases found in this strain in 1932 included 4 per cent mild mosaic, a trace of leafroll and no spindle tuber. Note the uniform stand, a distinguishing characteristic of potatoes which are practically free from mosaic, leafroll, and spindle tuber. In 1932, duplicate lots of this strain grown in Aroostook Farm, but not rogued during the three preceding seasons, developed 100 per cent mild mosaic, 4 per cent leafroll, and 12 per cent spindle tuber (see Figs. 8 and 9).